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APPLICATIONS OF RADIOISOTOPES FOR NAVAL FIELD ESTABLISHMENTS

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ABSTRACT

Techniques employing radioisotopes were investigated in order to determine their usefulness to Public Works Departments of the Naval Shore Establishment. These techniques include: absorption, detection of location, and backscattering. The last mentioned seemed to be the most promising and offered several applications for waterfront maintenance. Several Naval Field Establishments were visited during the course of the work to ascertain problem areas.

INTRODUCTION

This note is to report on possible applications of radioisotope techniques to the work of the Public Works Department of the Naval Shore Establishment. A search of the literature has indicated that these techniques have come into widespread use in governmental agencies and in industry whose functions overlap many of the operations and duties of the Public Works Department. This investigation was undertaken to determine applicability and suitability of these techniques to the Shore Establishment.

The main text which follows will set forth short discussions of some of the present applications of nuclear radiations in industry and State public works administration and some of the salient characteristics of nuclear radiations and their measurements, and finally will consider some applications for Naval uses which are available immediately and others which would require some development work.

Initial work in this investigation included an on-the-spot study of problems which might yield solutions by the uses of radiation. Fifteen Naval Activities were visited by investigators to gather this material. These included installations on both the Atlantic and Pacific oceans as well as BUDOCKS and DIRLANTDOCKS in Washington, D. C. Also people from other activities were interviewed. Table I gives a composite list of the problems encountered and their frequency of occurrence. Not all of the problems listed appear to be susceptible to solution at this time by the methods being described here, but those which are will be discussed in what follows.

SOME PRESENT APPLICATIONS OF RADIOISOTOPES

After the discovery of the methods of liberating nuclear energy, one of the immediate by-products was the easy availability of very intense sources of gamma rays. These sources were almost immediately put to industrial use in detecting flaws in heavy metal pieces. The energy of some of the radiations would penetrate several inches of steel and show holes or cavities in large castings and the like. Previously, these procedures involved the use of x-ray equipment with limitations inherent in the bulk of the equipment and the relative softness of the radiation. Gamma sources can be made quite small so that they can be inserted into holes and cavities to determine the soundness of the overlying metal, weld, pipe wall, etc. These uses are current today and the technology is continuing to develop new techniques based on this idea.[1]

There are many variations of these principles which have been used in industry. The manufacture of sheet metal or thin films of plastic, etc., has made extensive use of equipment which measures the thickness of the product, using nuclear radiation. The source of radiation is placed on one side of the sheet or film and the detector on the other. Variations in thickness can be detected with high precision, and the differences from the

desired thickness can be fed back to the rolls, etc. to correct them. The whole process can be made completely automatic in this way. The difference between the absorption of radiation by a column of liquid and an equal column of vapor has been used to make a liquid level indicator without the use of sight glasses. Another variation is the measurement of the thickness of air between two plates which has been used to measure the relative displacement of the supports to which the plates are attached.[2]

K. Preiss[3] has shown how absorption applications can be used to evaluate the quality of concrete. Voids, reinforcing steel, etc., which cause differences in density in the sample can be found and located at moderate depths and with some indications of the extent of such variations.

Radioactive substances can be "found" in the sense that the location of a small source can be determined. Patents have been issued covering the fabrication of golf balls incorporating a small amount of a suitable radioisotope so that the player may use a suitable detector to find the ball under adverse conditions. While this example is trivial, the same principle has been widely used in the laboratory to determine the kinetics of complicated chemical reactions, or the migration of biological substances in an animal or other living organism. In rather strict analogy, motor vehicles can be provided with weak radioactive sources and traffic past selected points can be measured. An improved technique which has been reported is to use several sources on the vehicles coded so that a particular one may be identified.

If radioisotopes are placed in liquid form, i.e. dissolved in a suitable liquid like water, and pumped through a pipe maze, it is possible to trace the piping, provided it is not too deeply buried in the ground. If, in addition, the fluid finds a leak, it will carry some of the radioisotope out through the opening, and this accumulation of radioactivity may be found.[4,5] This last method makes it possible to find a leak in piping which is buried too deeply to use a surface probe, if the line is large enough so that a detector can be pushed through the empty pipe. For very long lines, it may be necessary to drive the detector through by the normal working fluid, but recording becomes a problem. All sorts of methods of finding leaks this way have been described in the literature, but the technique is not very attractive because of the contamination of the environment with the radioactivity.

A third general class of industrial and governmental applications of radioisotope techniques is based on the physical principles of backscattering of radiation, to be described later. The uses include the monitoring and logging of oil wells[1], determination of the water content of soils[6,7,8] and concrete[9,10] and others. Of particular interest is the application of nuclear techniques to the inspection of roadway subgrades and surfaces.[11] The method is also applicable to numerous industrial processes, one such being the monitoring and control of the thickness of surface layers on metals, as an example.[12] The techniques and instrumentation

which form the bases of this class are being improved and extended. One advance is covered in the report that an instrument has been constructed which can distinguish between gold (and presumably other heavy materials) and any other metals or materials by backscattering and filtering the radiation from the object under examination.[13]

Backscattering methods, with their wide range of application and comparative safety offer encouraging possibilities of application in the field for monitoring and maintenance work, and will be stressed in the discussion which follows.

SOME PROPERTIES AND CHARACTERISTICS OF NUCLEAR RADIATIONS

There are four types of nuclear radiations which are of concern here, alpha, beta, gamma and neutrons. The first two are charged particles and the second two are uncharged. The presence of a charge means that the penetration of matter by the particle is difficult and the range is comparatively short. The uncharged rays, in contrast, have long ranges in most materials, ranging, in the case of gamma rays, from several inches of lead to many feet in water and similar materials. This is to be compared with a few inches of water for beta particles to a few thousandths of an inch for the heavier alpha rays. The neutron is unique in the sense that its behavior when penetrating matter depends greatly on the amount of hydrogen present. Collisions with hydrogen nuclei slow down energetic neutrons very rapidly until they have only thermal energies. Such slowly moving neutrons are very readily captured by most of the neighboring nuclei, whereas fast neutrons are not easily absorbed in this way. For instance, neutrons may penetrate a few feet of lead or many feet of dry rock or sand, but a comparatively short distance in water, wood, or other hydrogenous materials.

Beta and gamma rays are affected primarily by the electron clouds which surround the atoms and molecules which make up the material that they are penetrating. The density of electrons in the material depends on the gross density of the material itself, and its chemical composition, i.e. atoms with high atomic numbers scatter more effectively than those with lower atomic numbers. The same is true for alpha particles, but because of their large masses and high charge, their penetration is so small as to be of little concern here.

Radiation, when it enters matter, may be either absorbed or scattered. Some of the applications discussed above depend on the radiation being absorbed. The amount of absorption depends principally on the mass of material between the source of the radiation and the detector, the effects of chemical composition being relatively minor in this case. In order to measure the absorption of radiation, it is necessary to have the detector and source on opposite sides of the object being examined. This is the arrangement for the industrial devices which depend on absorption, such as thickness gauges, level indicators, etc.

Scattering, on the other hand, means that the direction of the particle is changed on collision with an electron in the material, but the particle is not lost. Scattering may also occur several times in the life of the particle, and may, in fact, completely reverse the direction of the particle. Instruments which depend on backscattering are using this phenomenon in their operation. A particle, ejected from a source, enters the test object, is scattered many times and then emerges, entering the detector. Some particles are not scattered back to the detector, of course, and are lost. It is the ratio of the numbers of particles detected to the numbers emitted by the source that is dependent on the mass and composition of the material being investigated. Also, since the source of radiation and the detector are on the same side of the material, they may be and frequently are incorporated into the same instrument. Backscattering is used with beta particles for small thicknesses, like thin coatings on metals, where the penetration is small. It is used with gamma rays where greater penetration is desired, as in measuring the compaction of earth or concrete, and it is used with neutrons for the measurement of hydrogen content, for measuring asphalt pavements for uniformity and for measuring moisture content in soil, etc.

APPLICATIONS FOR THE NAVAL SHORE ESTABLISHMENT

Several of the problems listed in Table I appear to be suitable for the application of radioisotope techniques at the present stage of development, while others will require additional investigations and refinements.

Such problems as soil density, asphalt density, etc. would appear to yield to types of instrumentation already on the market and widely used. Instruments are available which can analyze surface conditions to depths of 4 inches or more, for soil compaction, moisture content, asphalt depth and similar properties of interest to road builders and allied occupations. They have been developed to a high degree and are widely used by contractors and state inspection teams.[11] Their immediate application to air strips, road construction and similar operations where earth moving is involved, and the conditions warrant their use, is straightforward. Limited application to the inspection and evaluation of concrete in place would probably require additional study and development.

A sizeable fraction of the entries in Table I are concerned with the detection of corrosion and corrosion products on steel, roofing, sheet piling, etc. The routine or occasional inspection of structures and surfaces for this kind of incipient failure would seem to be most easily accomplished with suitable backscattering instruments. For the discovery of corrosion underneath thin coverings like paint, an instrument using scattered beta rays would be appropriate, while for the inspection of thicker specimens, the more highly penetrating gamma-ray devices would be indicated. For the measurement of the corrosion of sheet piling, for instance, where the steel is backed with dirt or concrete, the backscattering

of gamma rays would depend on the thickness of remaining metal. One would expect that these techniques would show conditions in the piling approaching failure, so that corrective action could take place. At the present time, as far as can be learned, there is little or no inspection of piling, so that repair must wait until failure has occurred. It is difficult, therefore, to estimate any expected savings as a result of inspection.

Unfortunately, a suitable instrument for such inspections is not readily available. Devices that have been found in the literature are applicable to factory production of sheet metal coatings, and would not be suitable for field application to inspection procedures. Suitable instruments, as far as has been determined, would have to be developed.

The design and construction of suitable backscattering instruments or at least the determination of the feasibility of the methods would appear to offer a reasonable chance of success. The radioactive sources and equipment necessary to carry out the development are quite modest and are well understood at the U. S. Naval Civil Engineering Laboratory. Most of the necessary equipment is also available, so that any effort in this direction could be started with minimum delay and at a modest cost.

Several of the items listed in Table I do not lend themselves to the inspection procedures outlined above. As one example, the penetration and retention of creosote in wood would be very difficult to determine using nuclear radiations. The gross chemical composition of wood is mainly chemical radicals of the form H-C-H and H-O-H (water) with some nitrogen. Creosote on the same basis is principally H-C-H. While physical and chemical differences are obvious, in backscattering or attenuation of nuclear radiation they are nearly the same, depending mainly only on the difference in scattering power between carbon and oxygen. Also, if an impregnated wood timber were immersed in water, the composition, from the nuclear standpoint, would still be the same, so there would be no differentiation among the various materials.

The location of pipe leaks using radioisotopes is certainly possible, but encumbered with added difficulties which make it unattractive unless all other methods fail. It involves, generally, loading the pipe with the radioisotope as a solution in some liquid, and then finding where the liquid leaked out. If the pipe is not buried too deeply, a surface probe can trace the pipe line, and locate the leak. The latter may require draining the pipe and searching for the activity which leaked out into the surroundings (usually the ground). Since all radioactive materials are potentially dangerous to living biological systems, the material drained from the pipe must be caught and stored. The disposal of these materials is involved and expensive because of the dangers inherent in contaminating the environment and personnel. The same applies to the ground around the leak which has been contaminated by the leak. The method will work for pipes buried only up to a foot or two, unless one uses very strong sources of the most energetic gamma rays, or one can place the detector in the pipe to find the spot where the activity leaked out.

The safeguarding of health in the use of open liquid sources usually requires extra personnel, trained in handling it, and the acquisition of a considerable amount of extra monitoring equipment. All of these considerations add up to adverse recommendations to the use of these techniques in the field. This, however, does not apply to the examination of a pipe for corrosion or scale build up by putting an encapsulated source in the pipe and measuring the attenuation through the walls as described earlier.

CONCLUSIONS AND RECOMMENDATIONS

A survey of selected Naval Activities has shown that there are several possibilities of incorporating methods employing radioisotopes into the operations of the Public Works Department. Of these the development of a suitable field instrument to measure states of corrosion of coverings of surfaces, like sheet piling, or of the underlying material, like painted sheet metal, seems to offer the most promise. Most of the apparatus, personnel, and experience are available at NCEL to undertake such a development.

It is recommeded that a program be set up to this end.

REFERENCES

1. Industrial Uses of Radioactive Materials. Arthur D. Little, Inc., Cambridge, Massachusetts, 1949.

2. R. P. Gardner and H. H. Koss. Alpha Gauge for the Measurement of Small Density Thicknesses. The Review of Scientific Instruments, Vol. 11, (1962), p. 1227.

3. Preiss, K. Measuring Concrete Density by Gamma-Ray Transmission. Materials Research and Standards, Vol. 5 (1965), p. 285.

4. Wilson, William A., and John, George S. Method of Determining Pipeline Leakage. U. S. Patent No. 3,084,259, April 2, 1963.

5. Beerbower, Alan and Murray, John L. Method of Using Radioactive Tracers. U. S. Patent No. 3,130,314, April 21, 1964.

6. McHenry, J. Roger. Theory and Application of Neutron Scattering in the Measurement of Soil Moisture. Soil Science, Vol. 95, (May 1963), p. 294.

7. Gardner, Wilford, and Kirkham, Don. Determination of Soil Moisture by Neutron Scattering. Soil Science, Vol. 73, (May 1952), p. 391.

8. Use of Neutron Meters in Soil Moisture Measurements. Progress Report of Task Force on Use of Neutron Meters, Committee on Hydrometeorology. Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division, Vol. 90, (November 1964), p. 21.

9. Preiss, K. and Newman, K. An Improved Technique for the Measurement of Density of Concrete and Soils with Gamma Radiation. A paper presented at the Fourth International Conference on Non-Destructive Testing. London, September 9-13, 1963.

10. Preiss, K. and Grant, P. J. The Optimization of a Neutron Scattering Water Content Gauge for Soils and Concretes. Journal of Scientific Instruments, Vol. 41, (1964), p. 548.

11. Road and Street, (June 1956), p.50.

12. Shumilovskii, N. N. and Mel'ttser, L. V. Radioactive Isotopes in Instrumentation and Control. Pergamon Press, (1964), p. 87.

13. ALL THATS GOLD MAY NOT GLITTER . . . ". Nucleonics Week. Vol. 6, (15 April 1965), p. 4.

TABLE I. PROBLEMS AT NAVAL ACTIVITIES

PROBLEM	FREQUENCY OF MENTION
Pipe Leaks	11
Detection of Slag and Rust Build-up	8
Roof Inspection	8
Soil Density	6
Corrosion Detection	6
Paint Thickness	5
Concrete Inspection	5
Creosote Penetration and Retention	4
Asphalt Density	4
Smoke Control	3
Weld Inspection	3
Wood Moisture	3
Engine Oil Analysis	2
Continuity of Asphalt Joints	1
Insecticide Flow Rate	1
Marine Borer Inspection	1
Pipe Line (buried) Tracing	1

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Techniques employing radioisotopes were investigated in order to determine their usefulness to Public Works Departments of the Naval Shore Establishment. These techniques include: absorption, detection of location, and backscattering. The last mentioned seemed to be the most promising and offered several applications for waterfront maintenance. Several Naval Field Establishments were visited during the course of the work to ascertain problem areas.